AIR QUALITY BALMERTOWN

Annual Report, 1977

Ministry
of the
Environment
Ontario

AIR QUALITY

BALMERTOWN

Annual Report, 1977

ONTARIO MINISTRY OF THE ENVIRONMENT
April, 1978

CONTENTS

SUMMARY

The Ontario Ministry of the Environment has conducted air quality assessment investigations in Balmertown since 1971. This report presents results of the 1977 programme, which included vegetation and soil studies, snow sampling, and air quality monitoring in the vicinity of two local gold mines.

Trembling aspen trees in 11 observation plots showed evidence of continued decline, but no relationship was established between this decline and emissions from mine roaster stacks. Symptoms of sulphur dioxide injury were observed on vegetation in a small area between the mines, and elevated sulphur concentrations were found in samples of tree foliage. All vegetation was free of visible signs of arsenic toxicity. Concentrations of arsenic in trembling aspen foliage decreased in 1977 to the point where most values were at, or near, levels considered acceptable. Arsenic in surface soil, while still high, also decreased substantially from 1976 to 1977. In contrast, soil in a small area near one of the mines contained unusually high arsenic and mercury concentrations which could not be attributed to a known emission source. A moss exposure experiment confirmed the presence of abnormal airborne arsenic and mercury at this site.

Arsenic in planted roadside trees and in vegetables from Balmertown residential gardens followed the same declining trend found in forest vegetation. Because of residual soil contamination, arsenic in a few vegetable samples was slightly above the acceptable limit set by the Canada Health Protection Branch.

Levels of arsenic in dustfall at all monitoring sites were low. Sulphation rates frequently were well above the Ontario air quality objective, indicating that average sulphur dioxide concentrations exceeded desirable levels. This situation was confirmed by limited data from a continuous monitor, which revealed a number of excursions above Ontario objectives for hourly and daily sulphur dioxide concentrations. Meteorological records confirmed that the gold mine roaster stacks were the sources of sulphur dioxide emissions.

INTRODUCTION

Since 1971, the Ontario Ministry of the Environment has undertaken an air quality assessment programme in Balmertown to assess the effects of atmospheric emissions from operations at two local gold mines. Both firms, Campbell Red Lake Mines Limited and Dickenson Mines Limited, use ore roasting processes which have, until recent years, been significant sources of emissions of arsenic trioxide and sulphur dioxide. In early 1974, Campbell installed equipment which effectively controlled atmospheric discharges of arsenic. At Dickenson, attempts to implement a somewhat different control system have met with numerous difficulties. Except for the entire growing season (May to October) in 1976 and most of the 1977 growing season, the Dickenson roaster has operated without emission controls. However, since 1974, the company has been required to shut down their roaster under conditions when winds could carry stack emissions over the town area. When the Dickenson controls are finally operational, airborne arsenic emissions from roasters at both mines will be almost totally eliminated. Discharges of sulphur dioxide, averaging about 20 tons daily from Campbell and 11 tons daily from Dickenson, have continued with no substantial change.

Earlier reports (1,2) documented investigations up to 1976, which included vegetation injury assessment, sampling of vegetation, soil and snow for chemical analysis, and the operation of a small air quality monitoring network. Studies along similar lines continued in 1977.

VEGETATION AND SOIL ASSESSMENT

FOREST AREAS

Observation Plots

Sixteen trembling aspen (*Populus tremuloides*) observation plots, 14 near Balmertown and two controls to the south, were first established in 1974. Eleven of the 16 (Figure 1) were maintained in 1977. The crown condition of trees in each plot was assessed in late August under a Canadian Forestry Service crown classification system which ranked trees into several classes based on the presence and degree of dieback symptoms. Trees were also inspected for evidence of air pollution injury and damage caused by insects or diseases. Tree diameters were measured in October.

Plot assessment in 1977 (Table 1) showed that about 72 percent of the trees were apparently healthy, 18 percent suffered some dieback, and 10 percent were dead. The greatest incidence of dieback and mortality occurred at plot 5, about mid-way between the two mines. Since 1974, trees in this plot also exhibited the highest incidence of decline (Table 2), though the growth rate of the survivors was better than average (Table 3). Because the adverse effects of air pollution on tree growth are often difficult to separate from those due to other influences, such as stand density and site quality, no conclusions can be drawn from the observation plot studies. To date, there is no clear evidence that mine emissions alone have resulted in a depression of tree growth rates. Observations will continue in 1978 to determine whether long-term trends can be detected.

Vegetation Injury

Light to severe injury from an infestation of forest tent caterpillar (*Malacosoma disstria*) was recorded throughout the survey area. Many trees had recovered by late August when our evaluation was undertaken. The severity of caterpillar damage was not related to distance from either gold mine. Some leaf-spot diseases were noted on tree foliage at several plot sites, but these were not associated with any significant damage.

Symptoms of acute sulphur dioxide injury were observed on foliage of trees, shrubs and herbaceous vegetation in a small area (4.1 hectares) between the two mines (Figure 2). Except for 1976, visible vegetation injury from this pollutant have been documented every year since 1972, when observations began. There was no evidence of visible vegetation damage caused by arsenic toxicity. Arsenic injury has not been seen since 1975, primarily because of the operation of effective arsenic emission controls at the Campbell mine and the suspension of ore roasting at Dickenson during the summers of 1976 and 1977. Pollutant dispersion at the latter mine was also improved in 1975 following completion of a taller stack.

Chemical Analysis

In 1977, triplicate samples of trembling aspen foliage and surface soil (0-5 cm) were collected in late August from the same 26 sites sampled in 1975 and 1976 (Figure 1). Additional samples of three depths of soil (0-5, 5-10, 10-15 cm) were also obtained near the Campbell mine (Figure 3). The foliage samples, each weighing about 500 g (grams) fresh weight, were obtained by

trimming outside leaf growth on the sides of trees facing the source to a height of about 6 m (metres) above ground. The collected leaves were placed in perforated polyethylene bags and stored under refrigeration (4^{0}C) until processed in the Ministry's laboratory facilities in Thunder Bay. Foliage was dried in an oven at 80^{0}C for 30 hours, then ground in a Wiley mill equipped with a 1-mm (millimetre) pore-size screen. At the Ministry's Toronto laboratory, powdered vegetation samples for iron analysis were subjected to ashing and acid digestion, after which iron was determined by atomic absorption spectrophotometry. For arsenic determination, powdered vegetation was digested in an acid mixture at low heat, followed by analysis with flameless atomic absorption spectrophotometry. For sulphur analysis, powdered sample material was formed into solid discs which were subjected to x-ray fluorescence.

Soil samples were obtained with a stainless steel corer, 2.5 cm in outside diameter. Before insertion of the corer, surface debris and loose organic matter were removed from the soil surface. At least 10 cores were pooled to form one sample, which was placed in a polyethylene bag to await processing. Sample material was spread on paper and air-dried for 48 hours, followed by coarse screening to remove stones and organic matter before fine screening through an 80-mesh sieve. Arsenic analysis for soil followed the same procedure described for vegetation. Mercury was determined by ultraviolet atomic absorption.

Table 4 presents chemical analysis results for arsenic, iron and sulphur in trembling aspen and soil. The arsenic data, plotted in Figure 4, reveal slightly elevated concentrations in tree foliage near the mines with a decline at more distant

points. There was little evidence of iron contamination, but sulphur levels near the mines were higher than those at the control sites. Arsenic in soil showed a pronounced gradient of decreasing levels with increasing distance from the two sources under investigation. A comparison between foliar concentrations of arsenic in 1977 with those in earlier years (Table 5) shows that levels continued to decrease, and values at most locations were near, or below, the current Ministry guideline of 8 µg/g. Although the arsenic content of soil still significantly exceeded the guideline of 25 µg/g throughout most of the survey area, it too declined substantially from an average of 760 µg/g in 1975 to 560 in 1976 and 380 in 1977. Although soil arsenic remains high, it is present as relatively insoluble arsenic trioxide and very little is taken up by local vegetation.

Findings from the special soil survey (Figure 3) near the Campbell mine were less satisfactory. Analysis results are summarized in Table 6, which indicates the presence of extremely high arsenic concentrations in soil outside the perimeter fence near Campbell's ore processing plant. The highest arsenic level recorded in surface soil was 7400 µg/g, and arsenic concentrations were still well above the Ministry's guideline at a depth of 10 to 15 cm. Results for mercury were similar to those in 1976. At five of the six sites, mercury levels in surface soil exceeded the guideline of 0.3 µg/g. The specific source of this contamination was not determined.

MOSS BAG EXPOSURE

Mosses have been found to be effective substrates for absorbing and retaining some types of airborne contaminants by a passive ion-exchange process. Techniques have been developed to suspend small quantities of moss in mesh bags at strategic locations to monitor the atmospheric environment (3). At Balmertown, bags of *Sphagnum* moss were exposed for 36 days (September 30 to October 5, 1977) at 29 sites near the mines (Figure 5). Monitoring was concentrated around Campbell Red Lake Mines, where high mercury levels had been found in soil in 1976. Each sample comprised about 4 g of oven-dried moss contained in a 10 x 20 cm envelope of fibreglass screening attached with Velcro strips to a supporting structure about 2.5 m above ground level. Exposed samples were collected and placed in polyethylene bags for refrigerated storage ($4^{o}C$) until convenient for processing in the Ministry's Regional Laboratory in Thunder Bay. Moss from the envelopes was dried at $80^{o}C$ for 30 hours, then ground in a Wiley mill equipped with a 1-mm pore-size screen. The analytical procedures, carried out at the Ministry's Toronto Laboratory, were the same as those described for vegetation. Zinc, a potential minor pollutant associated with the gold refining process, was included with the usual analyses for arsenic, iron and mercury.

Results are given in Table 7. The data indicate that there were no significant quantities of airborne iron or zinc present in the study area during the exposure period. For mercury and especially arsenic, however, there was evidence of airborne contamination near the Campbell mine, as illustrated in Figures 6a and 6b. These findings, and those from the snecial soil survey (Table 6), implicate a low-level point, rather than the roaster stack, as the probable emission source.

PLANTED ROADSIDE TREES

Foliage from white elm (*Ulmus americana*) and Manitoba maple (*Acer negundo*) trees at three locations in the residential part of Balmertown was sampled, processed and analysed for arsenic, iron and sulphur by the same procedures described for trembling aspen foliage. A summary of the arsenic data appears in Table 8, with comparable figures for 1973 to 1976. In 1977, arsenic concentrations had fallen to their lowest level since sampling began and were at, or near, the Ministry guideline of 8 μg/g. The difference between arsenic in leaves facing and away from the source had also disappeared. Sulphur and iron concentrations were low throughout.

VEGETABLE GARDENS

In 1977, as in former years, a range of representative vegetables was collected from three residential gardens in Balmertown and submitted for arsenic analysis. The sampling, processing and analytical procedures described for vegetation and moss also applied to garden produce, except that samples of the latter were washed in tap water before processing and analysis. Arsenic concentrations in 1977, and those for preceding years, are shown in Table 9. Assuming a fresh weight:dry weight ratio of 10:1, average levels of arsenic in edible portions of Balmertown garden samples were below the maximum acceptable limit of 1 μg/g, fresh weight, set by the Canada Health Protection Branch. A few individual samples marginally exceeded the 1 μ g/g limit. Although 1977 concentrations were generally satisfactory, and lower than those in earlier years, they were still higher than comparable

levels in control samples from Red Lake. Most of the contamination was attributed to residual arsenic contamination in Balmertown garden soils. Soil in one garden showed an unexpected sharp increase in arsenic in 1977, possibly as a result of applying an arsenic-containing pesticide.

SNOW SAMPLING

Snow sampling is frequently useful in assessing the kind, amount and extent of particulate pollutants near industrial sources of air pollution. Guidelines have been developed for concentrations of several elements in snow meltwater. Values exceeding the guidelines do not necessarily imply adverse environmental affects, but indicate that contaminants occur at concentrations significantly above those found in unpolluted snow.

In 1977, snow was collected from 24 Balmertown sites. Sampling locations (Figure 7) were the same as those in 1976. Sampling and analytical procedures were also the same (2), except that duplicate samples were obtained from each site in 1977. Table 10 presents the chemical analysis data. Compared with 1976, arsenic concentrations were generally lower in 1977, although values were above the guideline of 25 µg/l. All iron levels were below the 5 mg/l guideline. Although mercury concentrations were also below the guideline of 1 µg/l, the interpretation of the data is open to doubt because of melting conditions which occurred between the sampling and processing dates. It is suspected that some of the mercury may have evaporated during this time. Values for pH were normal. Total snow depth ranged from 42 to 69 cm and averaged 54 cm. No particulate matter was observed on or below the snow surface at any site.

AIR MONITORING

PARTICULATE POLLUTANTS

Dustfall

Dustfall, one of the most visible classes of air pollutants, comprises particulate matter which settles out from the atmosphere under the influence of gravity. It is measured by exposing open-top plastic jars to the air for 30 days and weighing the collected matter. Specific components of dustfall may also be analytically determined. Results are expressed in g/m^2 (grams per square metre) for 30 days. The Ontario air quality objectives for total dustfall are 7 g/m^2 per month, and 4.6 g/m^2, annual average. These values are equivalent to 20 and 13 tons per square mile which were, respectively, the monthly and annual objectives in use before conversion to metric units in January, 1977.

The four Balmertown monitoring sites are shown in Figure 8. Dustfall data are summarized in Tables 11 and 12. A few values for total dustfall were above the Ontario objectives, but these were not attributed to emissions from the mines. Sulphate levels were very low and all arsenic values (Table 12) were well within the guideline of 4 pounds per acre per year. Many monthly dustfall measurements were invalidated by contamination from bird droppings. Because of this problem, and the lack of evidence of industrial fallout on the town area in recent years, dustfall monitoring was terminated in December, 1977.

GASEOUS POLLUTANTS

Sulphation Rates

Sulphation rates are measured by exposing small plastic dishes, coated with lead dioxide, to the atmosphere for 30-day periods. Lead dioxide reacts with gaseous sulphur compounds to form lead sulphate. The amount of sulphate formed is analytically determined and results reported as mg SO_3/100 cm^2/day (milligrams of sulphur trioxide per hundred square centimetres per day). Although the coated plates will react with sulphur-containing gases such as hydrogen sulphide and organic sulphides, such compounds are not known to occur at significant levels in Balmertown. The plates are therefore assumed to be responding only to the presence of sulphur dioxide.

Sulphation rates for 1977 are given in Table 13. Many monthly values, particularly at stations 61010 and 61011, exceeded the Ontario air quality objective of 0.70 mg SO_3/100 cm^2/day, indicating that sulphur dioxide concentrations were often higher than acceptable. Stations 61010 and 61011 would be downwind of the mines more frequently than stations 61012 and 61013.

Sulphur Dioxide

Sulphur dioxide (SO_2), one of the world's major atmospheric pollutants, has many well-known adverse effects on human health, vegetation and property. In Balmertown, the only SO_2 sources of importance are emissions from the two mine roaster stacks, which together discharge about 30 tons of SO_2 daily when roasting operations are in progress.

In 1977, continuous sulphur dioxide measurements at station 61010 were carried out mainly with a Philips PW 9755 monitor with matching strip chart recorder. Unfortunately, because of instrument malfunction, very little valid data was acquired. The Philips instrument was replaced with a TECO pulsed fluorescence SO_2 analyser in December. Strip charts from both instruments were validated in Thunder Bay, then submitted to the Ministry's Air Resources Branch, Toronto, for determination of hourly SO_2 concentrations.

A summary of the available SO_2 data for 1977 appears in Table 14. On the 108 days when monitoring was carried out, the air quality objective of 0.25 ppm (parts per million), hourly average, was exceeded 31 times. The 24-hour objective of 0.10 ppm was exceeded twice, on April 24 and November 9 (Figure 9). The maximum hourly average was 0.56 ppm (about double the acceptable limit) compared with 0.54 in 1976. Wind directions, monitored at Red Lake airport, 5 km west of Balmertown, are related in Table 15 to the sulphur dioxide data for the year. About 90 percent of SO_2 readings were obtained when the monitor was downwind of the mines. Highest average concentrations were associated with winds from Campbell Red Lake Mines. Of the 31 hourly readings above the Ontario air quality objective, 23 were associated with northerly winds, 4 with northwesterly wind and 4 with northeasterly wind. Most of the excursions above the objective could therefore be attributed to emissions from the Campbell roaster.

REFERENCES

1. Griffin, H. D. 1976. Air quality, Balmertown. Annual Report, 1975. Ontario Ministry of the Environment.

2. Ontario Ministry of the Environment. 1977. Air Quality, Balmertown. Annual Report, 1976.

3. Goodman, G. T. and T. M. Roberts. 1971. Plants and soils as indicators of metals in the air. Nature 231:287-292.

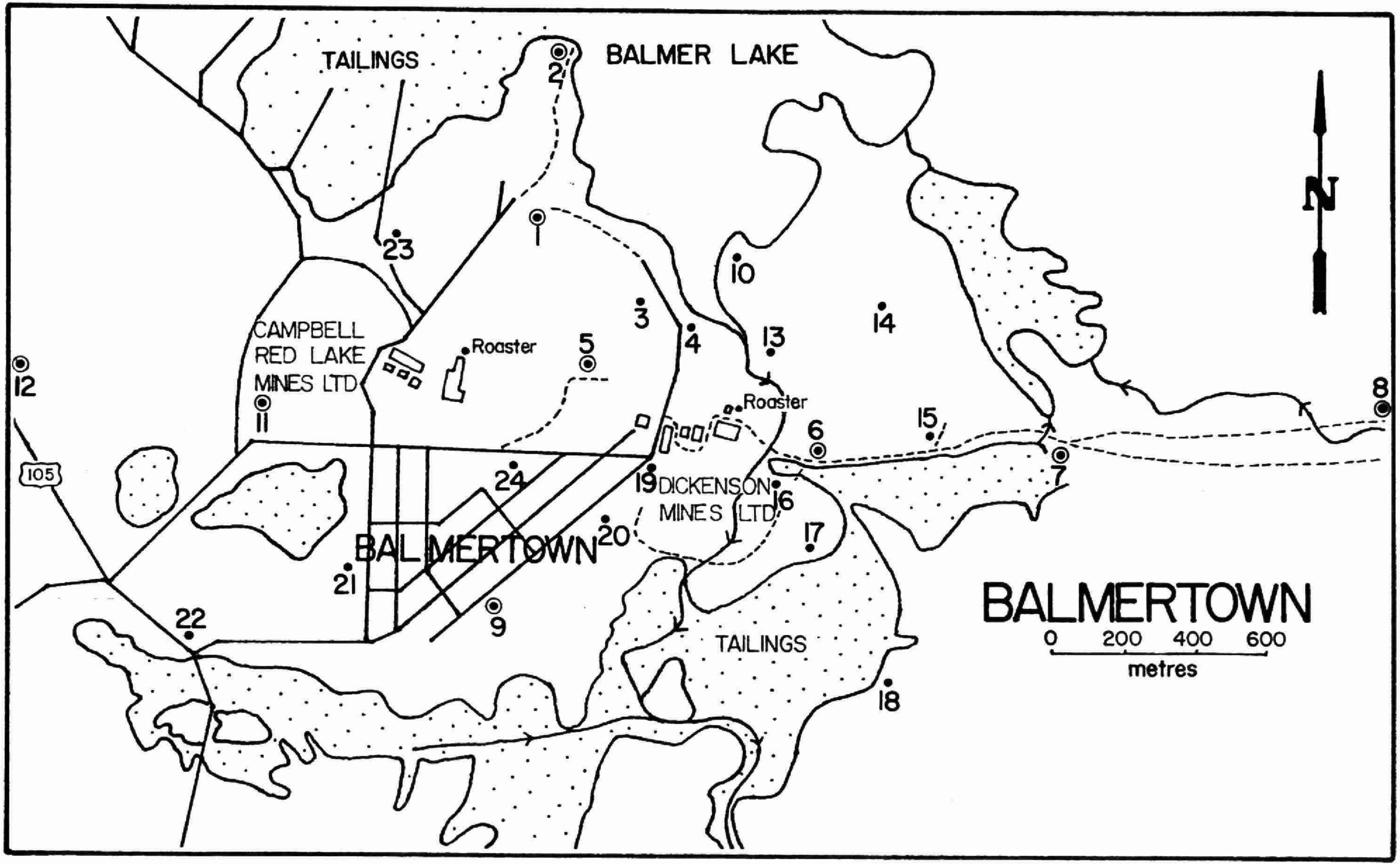

Figure I. Vegetation and soil sampling sites, 1977. (◉ Observation plots)

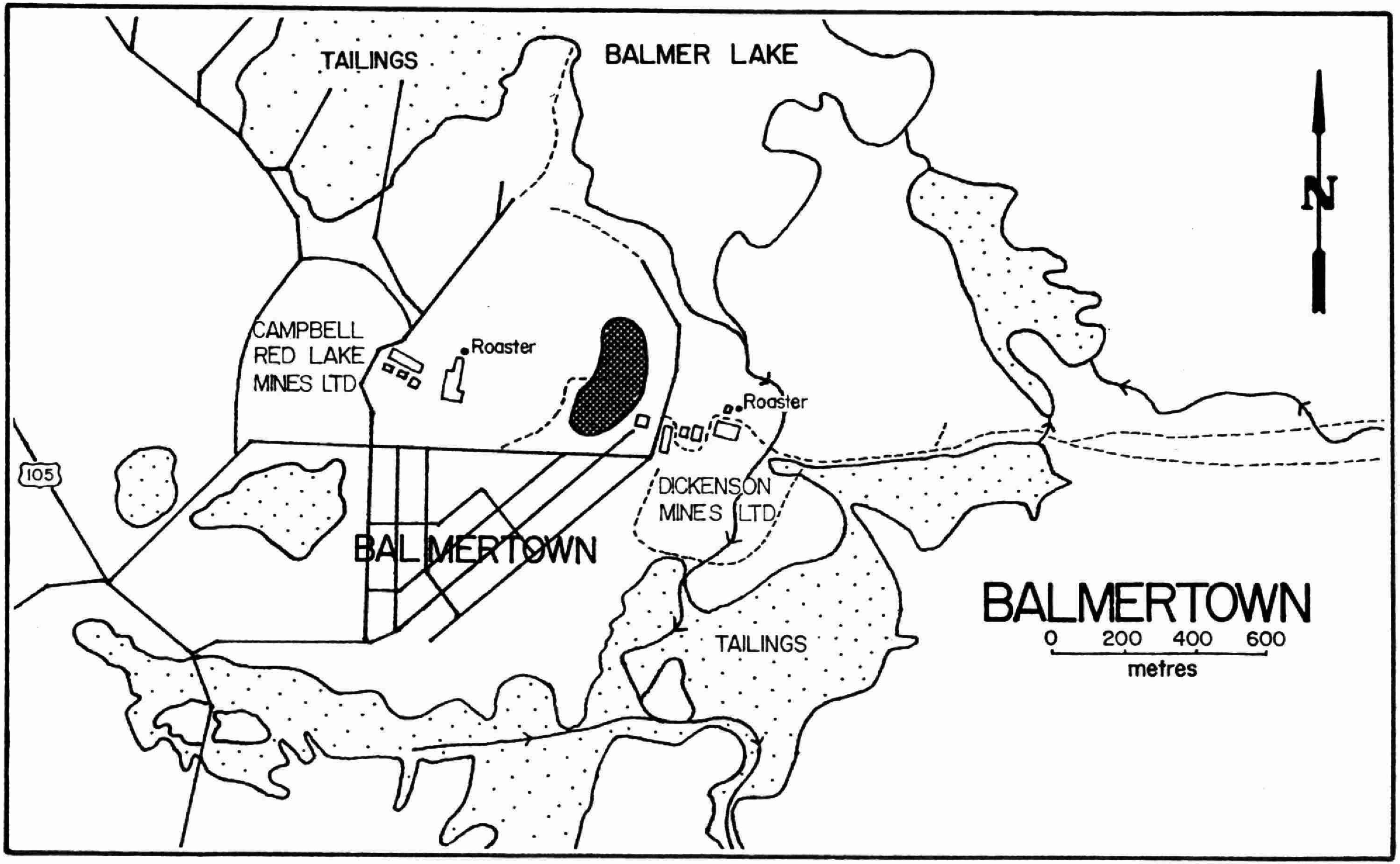

Figure 2. Sulphur dioxide vegetation injury, August, 1977.

Injury zone

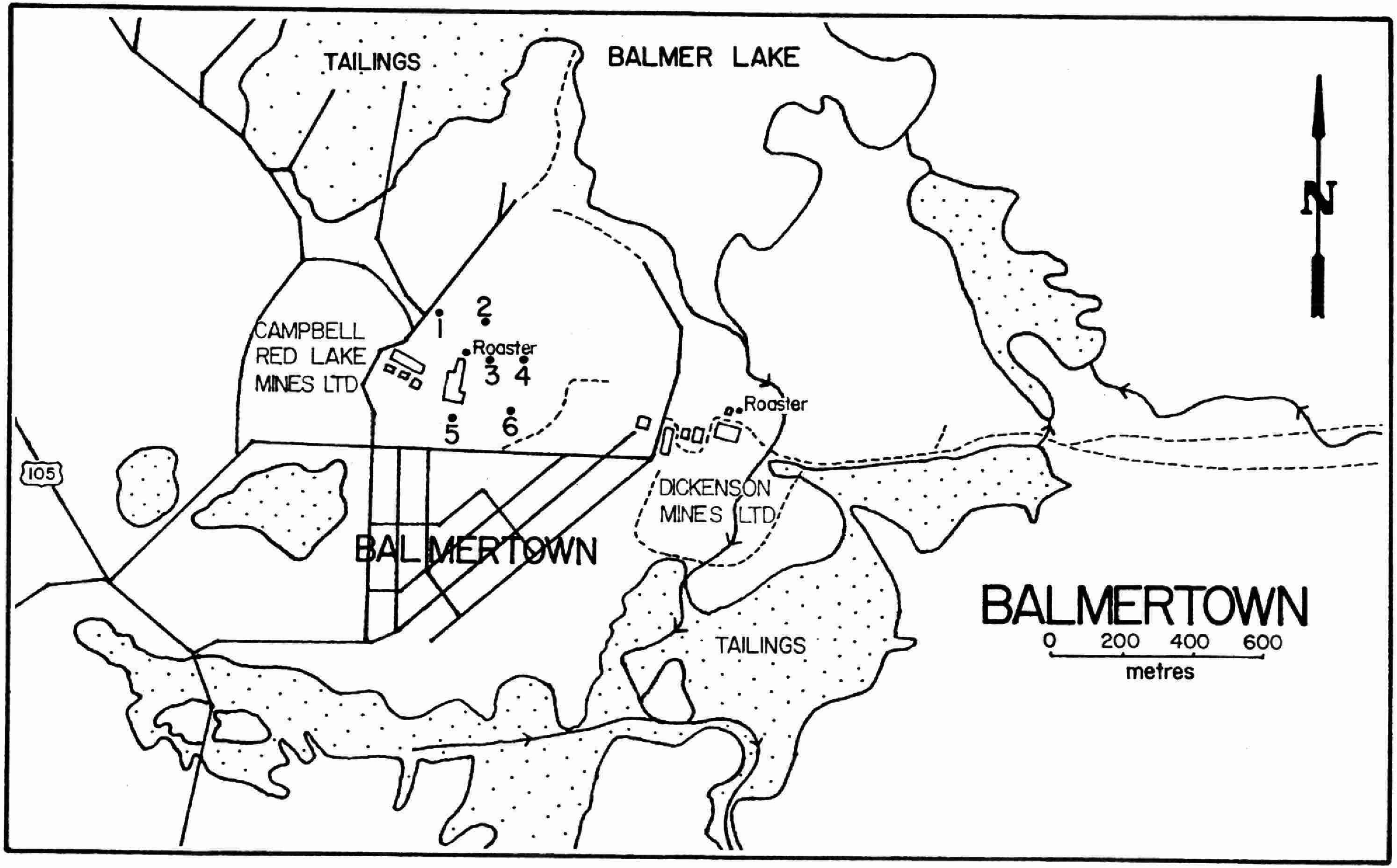

Figure 3. Special soil survey sampling sites, 1977.

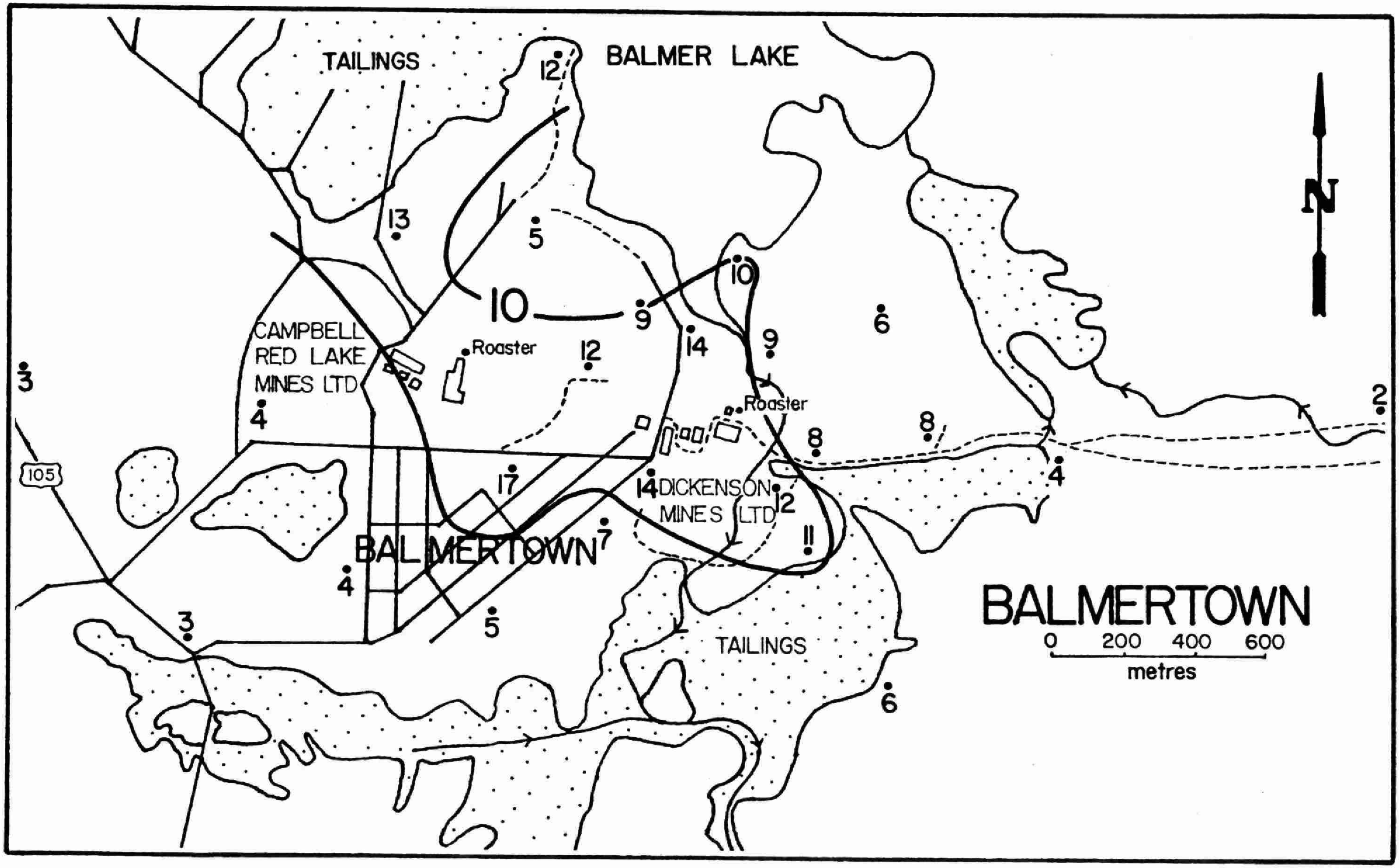

Figure 4. Arsenic content (µg/g, dry weight) in trembling aspen foliage, August, 1977.

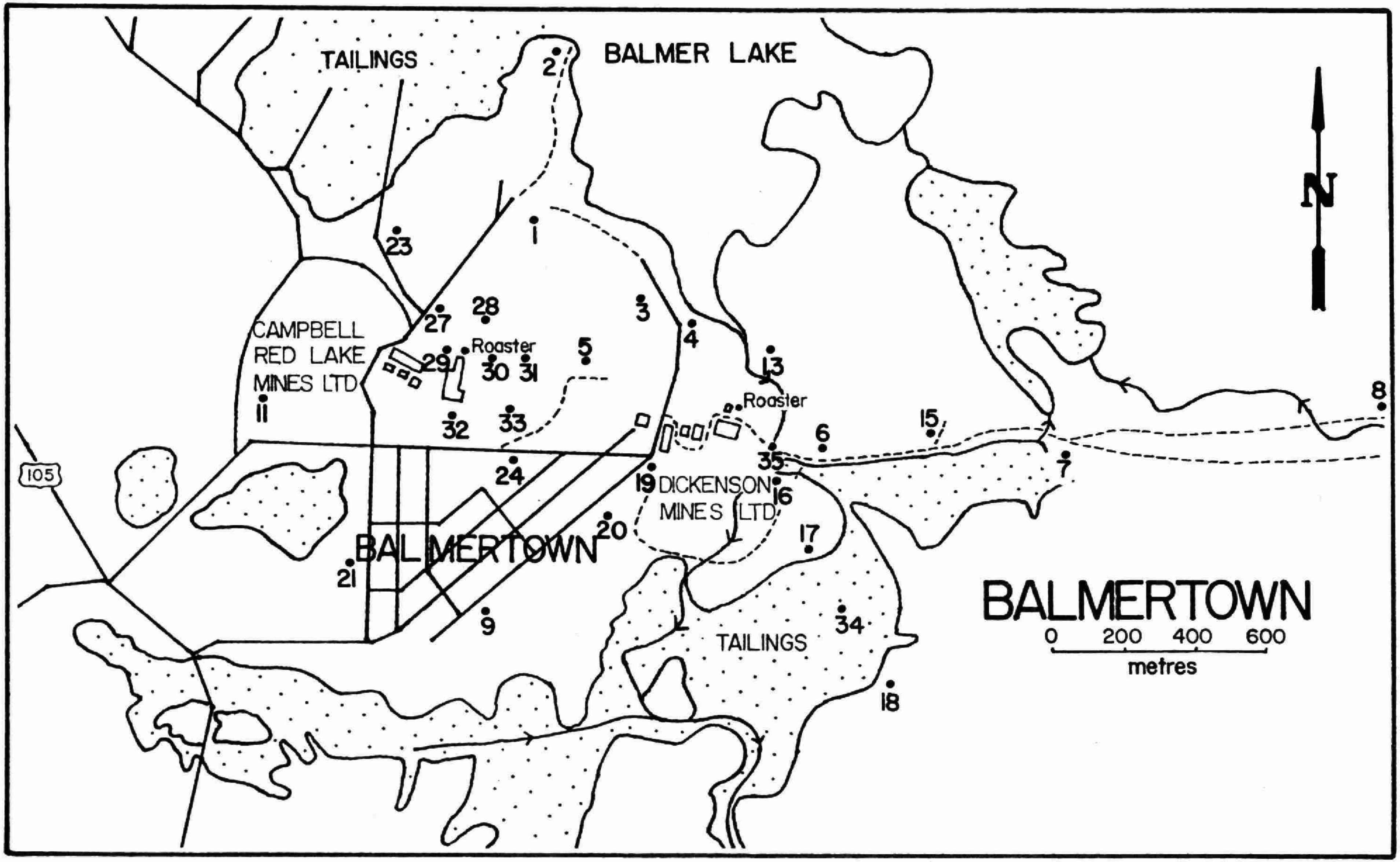

Figure 5. Moss bag exposure sites, 1977.

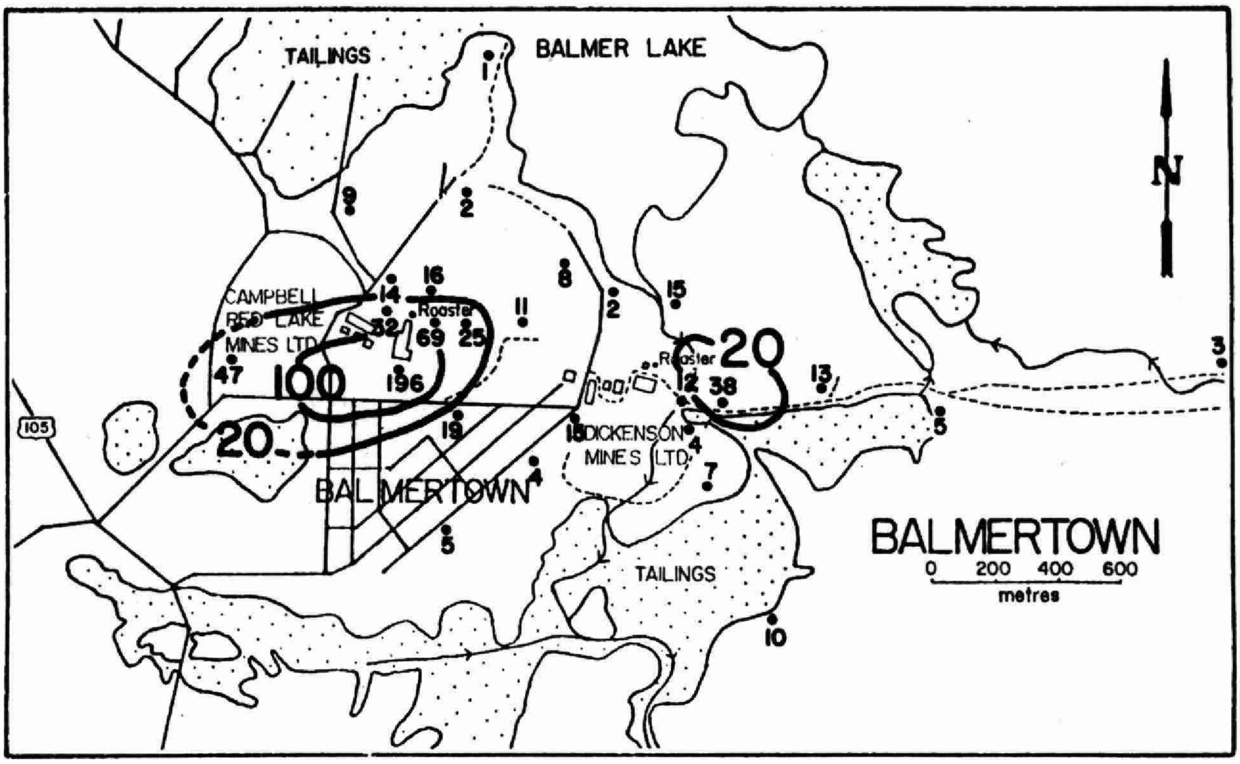

Figure 6 a. Levels of arsenic (µg/g, dry weight) in moss exposed in bags, August 30 to October 5, 1977.

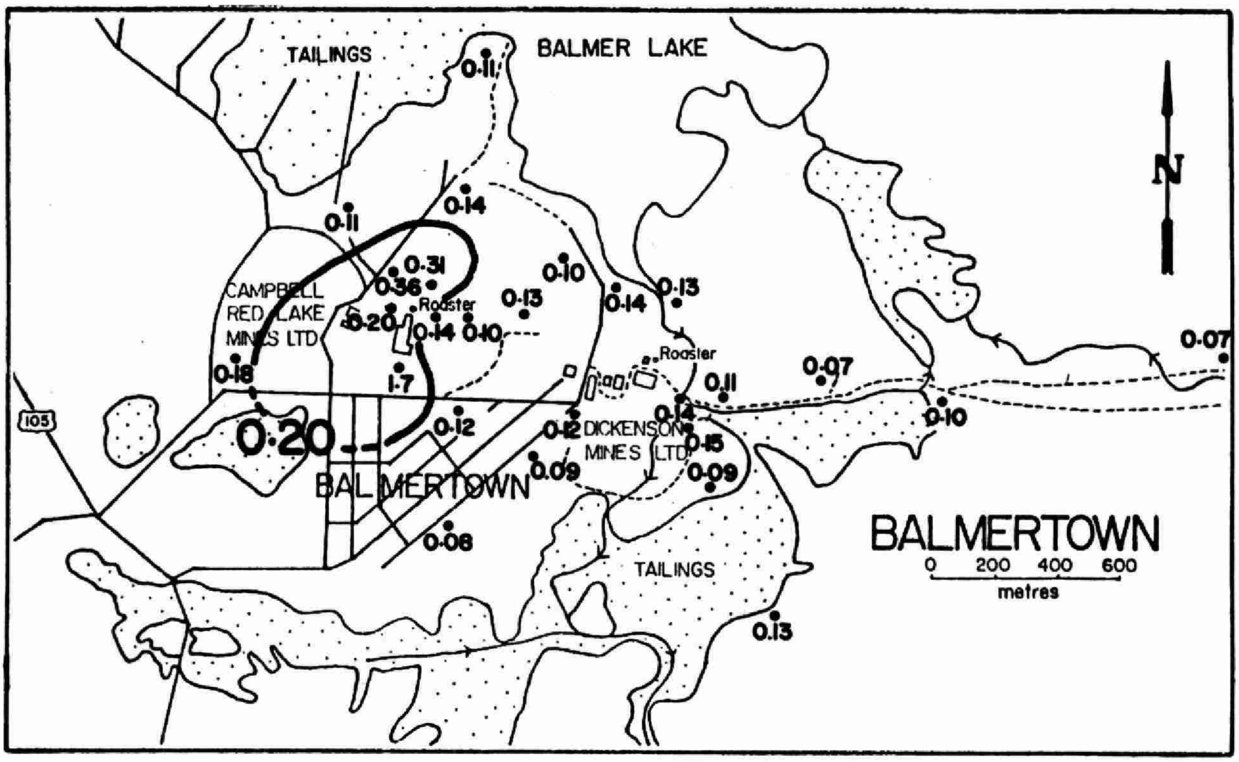

Figure 6 b. Levels of mercury (µg/g, dry weight) in moss exposed in bags, August 30 to October 5, 1977.

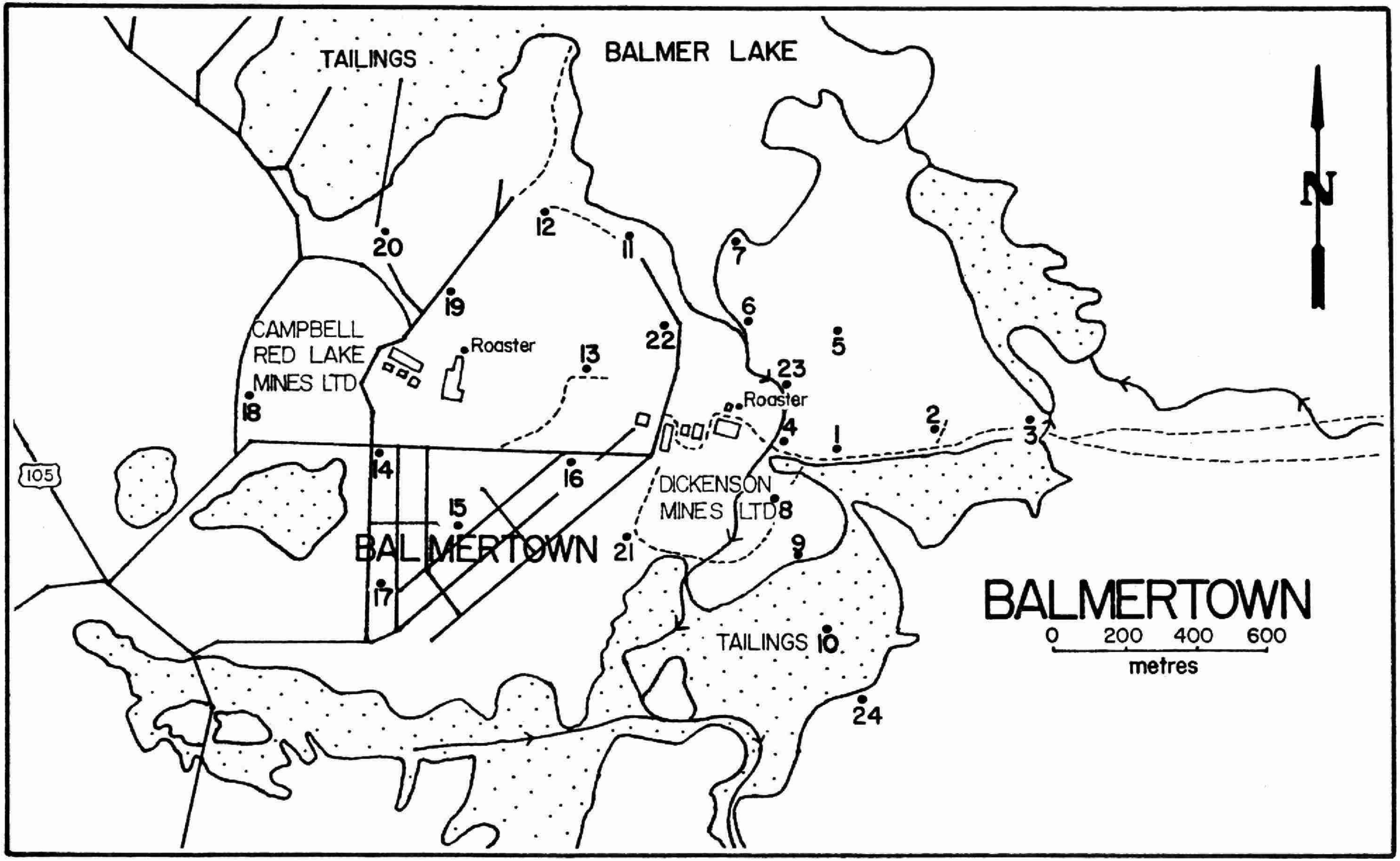

Figure 7. Snow sampling sites, March, 1977.

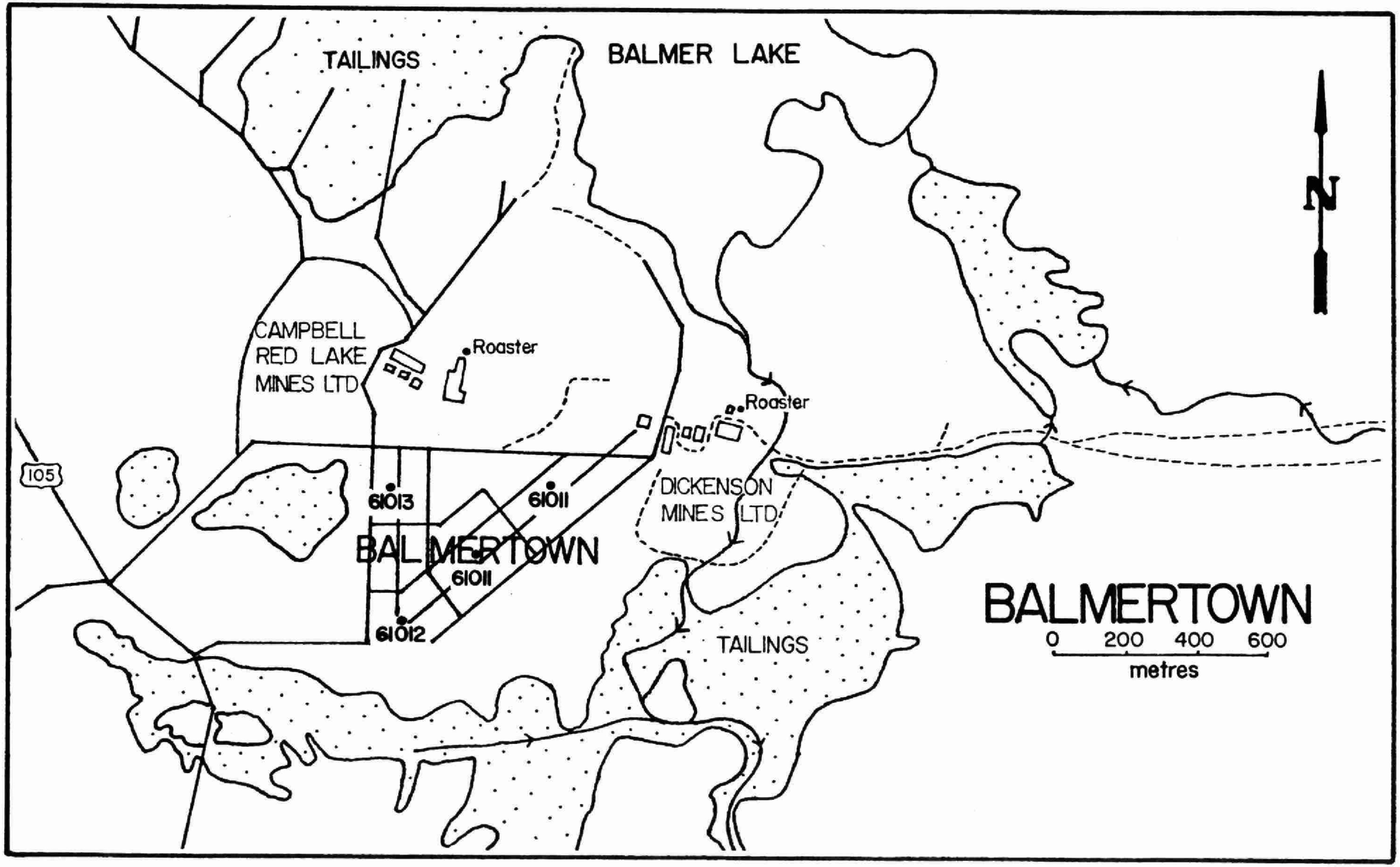

Figure 8. Air quality monitoring sites, 1977.

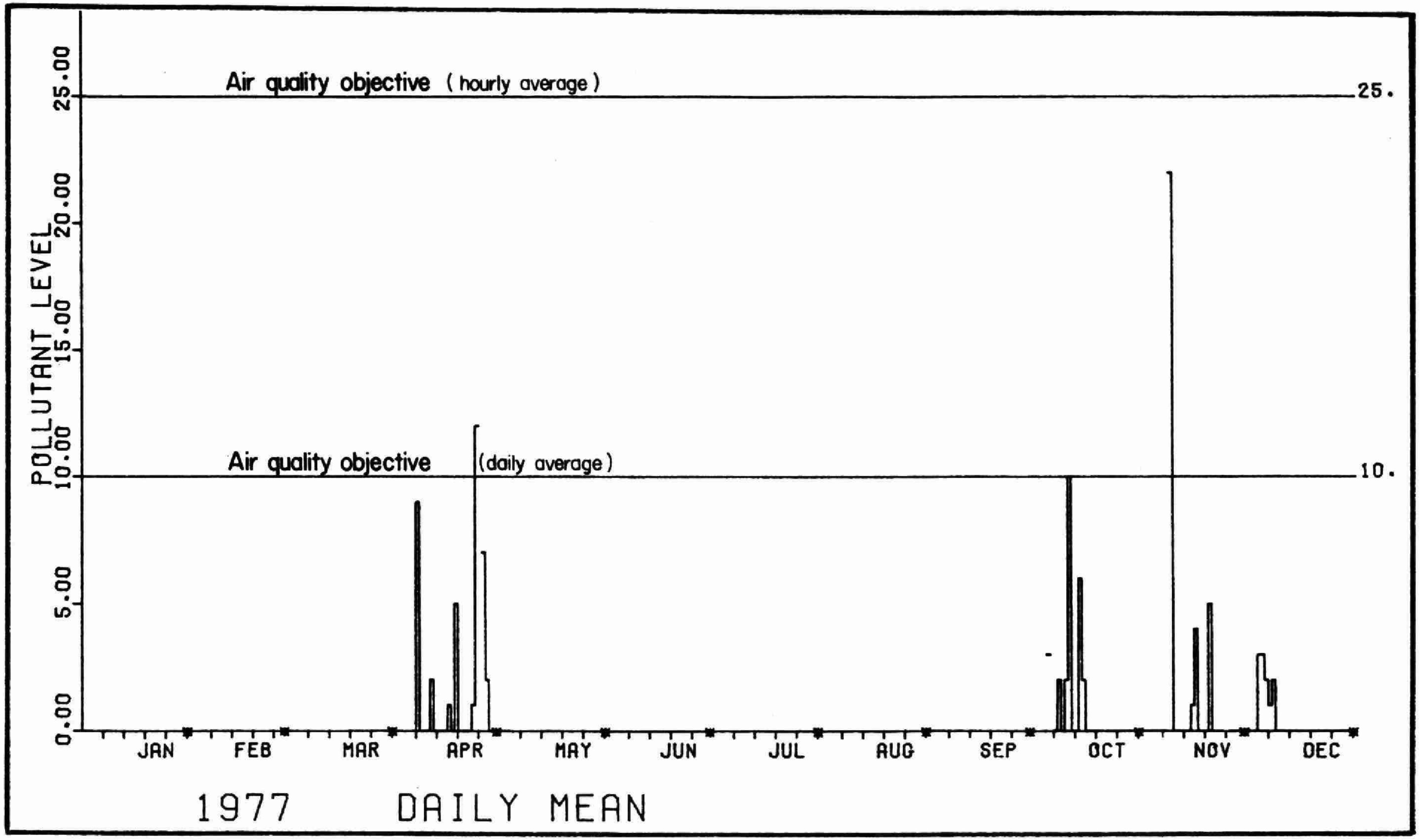

Figure 9. Daily mean sulphur dioxide concentrations (parts per hundred million) , station 61010., Balmertown, 1977.

TABLE 1. Crown condition of trees in observation plots, August, 1977.

Plot	Distance (metres) and direction from Campbell	Distance (metres) and direction from Dickenson	Apparently healthy	Slight dieback	Advanced dieback	Dead
1	415 NNE	830 W	12	3	2	3
2	880 NNE	1150 NNW	15	2		3
5	350 E	480 W	3	6	4	7
6	740 ESE	280 ESE	20			
7	1470 E	990 E	14	4		2
8	2670 E	1890 E	14	3	1	2
9	720 S	830 SW	16		2	2
11	640 WSW	1400 W	15	2	1	2
12	1440 W	2225 W	14	3	2	1
15	27200 SE (control)		18	2		
16	12500 S (control)		17	2		1

TABLE 2. Changes in crown condition of trees in observation plots from July, 1974 to August, 1977.

Plot	Crown condition		
	Unchanged	Improved	Declined
1	12		8
2	14		6
5	6		14
6	20		
7	16	1	3
8	14	1	5
9	16		4
11	15	1	4
12	14		6
15 (control)	18		2
16 (control)	18		2

TABLE 3. Diameters and diameter growth of trees in observation plots from 1973 to 1977.

Plot	Diameter, breast height (cm)[a]					Growth	
	1973	1974	1975	1976	1977	cm	%
1	3.9	3.9	4.1	4.1	4.1	0.2	5
2	5.8	5.7	5.8	5.9	5.8	0.1	2
5	4.3	4.3	4.4	4.3	4.8	0.5	12
6	2.7	2.8	3.1	3.3	3.4	0.7	6
7	6.1	6.2	6.3	6.6	6.6	0.5	8
8	8.9	9.0	9.2	9.2	9.4	0.5	6
9	5.6	5.7	5.7	5.8	5.9	0.3	5
11	5.3	5.4	5.5	5.6	5.8	0.5	9
12	7.8	7.9	8.1	8.1	8.4	0.6	8
15 (control)	4.2	4.6	4.9	4.8	4.9	0.7	17
16 (control)	3.8	3.9	4.1	4.1	4.2	0.4	11

[a]Average for all living trees.

TABLE 4. Concentrations of arsenic, iron and sulphur in not washed trembling aspen foliage and surface soil, August, 1977.

Site	Distance (metres) and direction from Campbell	Dickenson	Concentrations (μg/g, dry weight) Trembling aspen Arsenic	Iron	Sulphur	Soil (0-5 cm) Arsenic
10	850 ENE	510 N	10	110	4300	350
13	960 E	200 NE	9	100	4800	290
14	1200 E	500 NE	6	80	3300	210
6	740 ESE	280 ESE	8	120	4300	470
15	1310 E	500 E	8	95	5000	230
7	1470 E	990 E	4	85	2300	110
8	2670 E	1890 E	2	70	1600	420
16	1010 ESE	290 SSE	12	100	3800	240
17	1150 ESE	465 SSE	11	160	4800	190
18	1470 SE	900 SSE	6	85	5100	25
19	640 ESE	305 SW	14	210	5200	380
20	625 SE	500 SW	7	100	5200	230
9	735 S	900 SW	5	120	3600	160
24	370 SSE	670 WSW	17	180	3600	610
21	670 SSW	1170 WSW	4	110	1700	120
22	1150 SW	1710 WSW	3	90	2500	85
5	350 E	480 W	12	95	6400	890
11	640 WSW	1400 W	4	70	2400	220
12	1440 W	2225 W	3	80	2700	30
23	400 NW	1140 WNW	13	220	3800	1800
3	480 ENE	510 NW	9	100	6400	940
1	415 NNW	830 NW	5	110	4800	830
4	670 E	225 NNW	14	160	7400	230
2	880 NNE	1150 NNW	12	140	4000	160
25	27200 SE	(control)	< 1	140	1900	9
26	12500 S	(control)	< 1	70	1800	9

TABLE 5. Comparison between arsenic content (μg/g, dry weight) of not washed trembling aspen foliage for the years 1972 to 1977[a].

Site	1972	1973	1974	1975	1976	1977
1	-	-	26	31	10	5
2	-	-	22	26	6	12
5	160	550	29	33	18	12
6	78	400	200	260	50	8
7	21	81	43	29	5	4
8	-	-	14	18	4	2
9	260	410	19	6	6	5
11	98	110	10	7	2	4
12	27	41	9	9	4	3
Controls	<1	8	3	2	<1	<1

[a]Values for 1972-1974 based on single samples, those for 1975-1977 based on triplicate samples.

TABLE 6. Average arsenic and mercury concentrations (μg/g, dry weight) in three depths of soil collected near Campbell's ore processing plant, September, 1977.

Site	Distance (metres) and direction from source[a]	Arsenic			Mercury		
		0-5 cm	5-10 cm	10-15 cm	0-5 cm	5-10 cm	10-15 cm
1	150 NW	6200	520	350	0.8	0.1	<0.1
2	120 NNE	2500	800	500	2.6	0.5	0.7
3	85 E	7400	1100	1700	13.0	0.4	0.1
4	190 E	5800	330	140	2.9	0.1	<0.1
5	195 S	3500	240	180	0.5	<0.1	<0.1
6	210 SE	840	180	80	0.2	<0.1	<0.1
Control	16000 S	15	<5	<5	<0.1	<0.1	<0.1
Control	27200 SE	<5	<5	<5	<0.1	<0.1	<0.1

[a]Source arbitrarily designated as Campbell roaster stack.

TABLE 7. Levels of arsenic, iron, mercury and zinc (μg/g, dry weight) in moss exposed August 30 to October 5, 1977, at Balmertown.

Sample Site	Arsenic	Iron	Mercury	Zinc
1	2	1300	0.14	42
2	1	1300	0.11	42
3	8	1300	0.10	34
4	2	1400	0.14	33
5	11	1400	0.13	84
6	38	1400	0.11	41
7	5	1400	0.10	52
8	3	1200	0.07	31
9	5	1400	0.08	110
11	47	1300	0.18	110
13	15	1400	0.13	45
15	13	1300	0.07	44
16	4	1400	0.15	37
17	7	1300	0.09	37
18	10	1300	0.13	33
19	15	1600	0.12	42
20	4	1300	0.09	40
23	9	1400	0.11	35
24	19	1300	0.12	44
27	14	1400	0.36	41
28	16	1300	0.31	50
29	32	1500	0.20	50
30	69	1600	0.14	45
31	25	1400	0.10	38
32	200	1800	1.70	50
35	12	1400	0.14	42
25 (control)	<1	1300	0.09	37
26 (control)	1	1300	0.12	39
Unexp.[a] control	1	1400	0.09	41
Unexp. control	1	1400	0.13	43

[a]Unexposed

TABLE 8. Comparison between average aresnic content ($\mu g/g$, dry weight)[a] in not washed Manitoba maple and white elm foliage from planted roadside trees.

Year	Side of tree	Distance (metres) and direction from Dickenson - 525 SW / Campbell - 480 SE	1005 SW / 610 S	1090 SW / 430 SW	8000 SW (control)
1973	Facing	504	734	352	19
	Away	323	432	202	25
1974	Facing	70	36	20	4
	Away	31	21	12	-
1975	Facing	138	76	34	4
	Away	58	46	18	-
1976	Facing	18	12	20	2
	Away	18	9	11	-
1977	Facing	13	6	8	<1
	Away	16	5	8	-

[a]Values for 1973 and 1974 based on single samples, those for 1975-1977 based on triplicate samples.

TABLE 9. Comparison between average arsenic content[a] (μg/g, dry weight) in washed vegetables and surface soil (0-5 cm) from three Balmertown gardens, 1973 to 1977.

Sample	Balmertown 1973	Balmertown 1974	Balmertown 1975	Balmertown 1976	Balmertown 1977	Red Lake (control) 1973	Red Lake (control) 1974	Red Lake (control) 1975	Red Lake (control) 1976	Red Lake (control) 1977
Potato - leaves	-	18	24	15	9	-	4	2	2	2
- tubers	-	2	2	2	<1	-	<1	<1	<1	<1
Beet - leaves	180	8	8	7	7	8	<1	<1	<1	<1
- roots	40	3	9	4	6	2	<1	<1	<1	<1
Lettuce - leaves	140	9	18	12	7	-	2	<1	<1	<1
Rhubarb - leaves	300	6	-	-	3	7	<1	-	-	<1
- stalks	30	2	-	-	<1	3	<1	-	-	<1
Onion - leaves	-	28	-	-	12	-	1	-	-	<1
- bulbs	-	6	-	-	9	-	<1	-	-	2
Soil - garden	-	160	150	60	360	-	10	10	8	7
- lawn	-	570	450	210	340	-	14	10	9	8

[a]Values for 1973 and 1974 based on single samples, those for 1975-1977 based on triplicate samples.

TABLE 10. Levels of arsenic, mercury, iron and pH in snow meltwater from samples collected at Balmbertown in January, 1976, and March, 1977.

Site	Arsenic (µg/l)		Iron (mg/l)		Mercury (mg/l)		pH	
	1976	1977	1976	1977	1976	1977	1976	1977
1	260	140	2.1	1.0	120	<50	3.8	4.4
2	290	120	1.5	0.8	75	<50	3.5	4.1
3	230	120	1.5	0.8	45	<50	3.5	4.1
4	260	30	1.6	0.2	320	<50	3.5	4.1
5	80	70	0.7	0.7	80	80	3.5	4.4
6	170	160	0.7	1.5	320	170	3.5	4.2
7	420	20	2.3	2.4	105	<50	3.5	5.2
8	150	260	1.0	1.8	560	160	3.7	4.4
9	80	170	0.6	1.4	4000	50	3.6	4.3
10	90	250	1.1	1.4	300	<50	3.5	4.2
11	350	50	2.1	0.4	170	<50	3.5	4.2
12	280	40	2.3	0.3	120	<50	3.6	4.6
13	100	120	0.8	1.2	720	160	3.6	4.4
14	60	90	0.8	0.8	550	<50	3.6	4.4
15	170	180	1.7	2.2	180	140	3.4	4.2
16	200	280	0.6	2.0	670	210	3.6	4.2
17	<10	60	0.2	1.8	<10	60	3.5	4.8
18	40	100	0.4	0.5	120	70	3.6	4.2
19	200	120	1.2	0.9	220	160	3.5	4.2
20	180	60	3.6	0.6	95	<50	4.5	4.4
21	60	340	0.5	2.8	130	60	3.4	4.4
22	450	130	3.0	1.0	1100	<50	3.5	4.2
23	190	190	1.0	1.4	100	60	3.3	4.4
24	90	120	0.6	1.2	120	50	3.5	4.6
Control	<10	<10	0.2	0.3	16	<50	3.4	4.5
Control	<10	<10	0.6	0.2	20	<50	3.5	4.0

TABLE 11. Total dustfall and soluble sulphate in dustfall, Balmertown, 1977.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
		Total dustfall ($g/m^2/30$ days)												
61010	Lassie/Dickenson	5.0	-	-	7.6[a]	3.3	4.8	-	4.2	-	5.5	5.1	-	5.1
61011	113 Dickenson Road	7.2	4.0	-	2.3	3.9	-	-	1.2	5.3	-	-	-	4.0
61012	Fifth/Dickenson	-	-	-	5.6	5.5	8.2	-	3.7	-	-	-	-	-
61013	273 Fifth Street	1.2	3.4	-	3.8	9.9	3.8	-	3.4	2.8	7.2	2.1	-	4.2
		Soluble sulphate in dustfall ($g/m^2/30$ days)												
61010	Lassie/Dickenson	0.2	-	-	0.2	0.3	1.1	-	0.3	-	0.1	0.4	-	0.4
61011	113 Dickenson Road	0.3	0.2	-	0.1	0.2	-	-	0.3	0.3	-	-	-	0.2
61012	Fifth/Dickenson	-	-	-	<0.1	0.3	0.9	-	0.2	-	-	-	-	0.4
61013	273 Fifth Street	<0.1	0.2	-	<0.1	0.2	0.4	-	0.1	-	0.4	0.1	0.2	0.2

[a]Values exceeding air quality objectives of 7.0 (monthly) or 4.6 (annual average) are underlined.

TABLE 12. Arsenic in dustfall (lbs/acre/year), Balmertown, 1977.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
61010	Lassie/Dickenson	0.6	-	-	-	0.3	1.0	-	0.1	-	0.2	0.2	-	0.4
61011	113 Dickenson Road	0.7	1.3	-	1.3	0.4	-	-	0.3	0.6	-	-	-	0.8
61012	Fifth/Dickenson	-	-	-	-	0.3	1.7	-	0.1	-	-	-	-	-
61013	273 Fifth Street	0.5	0.7	-	<0.1	0.2	1.7	-	1.2	-	0.2	0.1	-	0.6

TABLE 13. Sulphation rates (mg SO_3/100 cm^2/day), Balmertown, 1977.

Station	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
61010	Lassie/Dickenson	.49	1.73[a]	.54	.89	.75	1.47	1.69	.23	.71	.99	1.49	.14	.93
61011	113 Dickenson Road	1.86	1.45	.59	.94	.99	.75	1.69	.38	.15	.45	.74	.57	.88
61012	Fifth/Dickenson	.22	.92	.47	.20	.25	.62	.72	.03	.57	.47	.70	.10	.44
61013	273 Fifth Street	.12	.21	.62	.31	.30	.62	.43	.02	.23	.47	.38	.14	.32

[a]Values exceeding monthly air quality objective (0.70 mg SO_3/100 cm^2/day) are underlined.

TABLE 14. Number of hours of data for different concentration categories of sulphur dioxide in 1977 at station 61010, Balmertown.

Month	Days of data	Hours of data for concentration categories[a] of: 0-4	5-10	11-14	15-25	26-39	>40	Maximum value Hourly	Daily
Jan									
Feb									
Mar									
Apr	24	489	17	6	17	4	5	48	12
May	4	82	0	0	0	0	0	0	0
Jun									
Jul									
Aug									
Sep									
Oct	25	527	7	1	7	5	4	46	10
Nov	27	576	7	5	3	6	7	56	22
Dec	28	640	12	6	2	0	0	17	3
Year	108	2314	43	18	29	15	16	56	22

[a]Parts per hundred million.

TABLE 15. Relationship between wind direction and sulphur dioxide levels in Balmertown, 1977.

Wind direction	Number of hours when SO_2 was monitored	Average concentration[a] when SO_2 was monitored
South	4	3
Southwest	5	1
West	4	6
Northwest	45	11
North	93	15
Northeast	60	8
East	17	5
Calm	9	3

[a]Parts per hundred million.